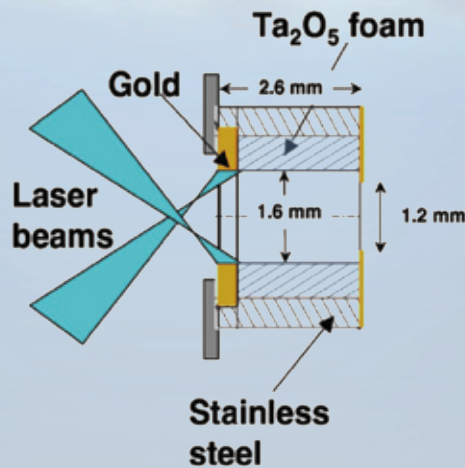


Photons Fusion Newsletter

Building a Better Hohlraum for the National Ignition Facility

In 2005, Lawrence Livermore National Laboratory (LLNL) scientists Mordy Rosen and Jim Hammer predicted that a better-performing laser-heated hohlraum could be fashioned using low-density “foam” walls. Their analysis has now been verified by experimental results.

The hohlraum in a conventional indirect inertial confinement fusion (ICF) target, such as those used at the National Ignition Facility (NIF), is a gold cylindrical shell about the size of a pencil eraser that surrounds the target capsule. When irradiated by lasers, the hohlraum emits a “bath” of X-rays that heat and vaporize the outer layer of the BB-sized target capsule, causing it to rapidly implode. The resulting temperature and pressure force



Design and dimensions of the foam-walled tantalum-oxide hohlraum target.

laser powers and thus lower costs of ‘wear and tear’ on the laser,” Rosen explains.

When conventional solid-gold hohlraum walls are heated by laser-produced X-rays, the ablated, or vaporized, mate-

“More efficient hohlraums let us implode the same ignition target at lower laser powers and thus lower costs of ‘wear and tear’ on the laser”

—Mordy Rosen

the hydrogen nuclei to fuse and ignite in a controlled fusion reaction.

The amount of X-ray radiation available depends on the initial conversion efficiency of laser light into primary X-rays and on the X-ray re-emission efficiency of the hohlraum walls. Improving the flux of X-rays that reach the capsule is important, because improvements in target performance mean increased operating margins for a given laser capability.

“More efficient hohlraums let us implode the same ignition target at lower

rial from the solid hohlraum walls streams back into the hohlraum interior. “This kinetic energy is wasted,” Rosen says, “as it does not drive the ICF capsule. Low-density high-Z (high-atomic-number) foams have far less of this hydrodynamic motion and hence are more efficient, since more of the energy is used in heating the foam walls which radiate onto the capsule and drive it to ignition.”

Using analytic theory and numerical simulations, Rosen and Hammer showed that low-density high-Z foams can lower

Photons & Fusion is a monthly review of science and technology at the National Ignition Facility & Photon Science Principal Directorate, Lawrence Livermore National Laboratory. For more information, submit a question at lasers.llnl.gov/forms/contact_us.php.

October 2008

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wall loss, and thus raise efficiency, by 10 to 20 percent. They also derived an analytic expression for the optimal density for any given drive temperature and laser pulse duration that will achieve this increase in hohlraum efficiency.

In a recent article in *Physical Review Letters* (*Phys. Rev. Lett.* 101, 035001 (2008)), a research team from LLNL and the U.K. Atomic Weapons Establishment led by NIF's Peter Young report on the first experimental demonstration of the Rosen-Hammer theory. The team used

laser beams at the OMEGA laser facility at the University of Rochester to irradiate hohlraums whose walls were made of tantalum oxide foam of 4 grams per cubic centimeter (g/cc) (as high a density as could be made) and 0.1 g/cc and heat them to 100 electron volts (eV).

For those drive conditions, the Rosen-Hammer theory predicted that the foam density wall of 0.1 g/cc would be optimal. Their analytic theory and computer simulations predicted that, when compared to the 4 g/cc hohlraum with the

same laser drive, a 4-eV hotter hohlraum would be achieved, producing an unambiguous 17 percent brighter X-ray signal for the experimenters to detect.

"That is exactly what Young's team observed," says Rosen. "This success could motivate more work in creating low-density gold foam walls and perhaps move on to cocktail foams, whose combination of materials could optimally reflect more X-rays back into the hohlraum and increase its efficiency even further."



The LFEX compressor chamber, part of Japan's Fast Ignition Realization Experiment (FIREX-I).

Novel Laser Pulse Compressor Design Boosts LFEX Project

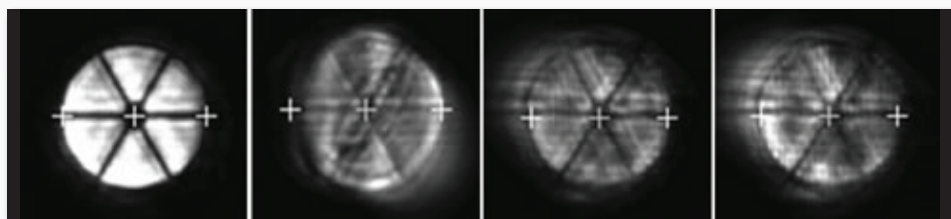
When Mike Rushford of the Photon Science & Applications (PS&A) program visited the LFEX short-pulse laser facility being built in Osaka, Japan, about three years ago, he turned out to be more than a casual tourist. Mike worked with his hosts to develop a new double-pass, high-energy laser pulse compressor design for the facility.

Based on two grating apertures with two gratings per aperture, the new design has a number of features that make it tolerant to some alignment errors and manufacturing variations. A paper by Mike, Jerald Britten and Chris Barty of PS&A and colleagues describing features of the compressor was published recently in *Optics Letters* (*Opt. Lett.* 33, 1902-1904 (2008)).

New Template Improves Laser Beam Alignment

Livermore researchers Abdul Awwal and Richard Leach and colleagues from Clemson University have developed a new analytical template to accurately estimate the center of a NIF beamline with good image quality. Video images of laser beams are used to determine the position of the beams for alignment purposes. Algorithms process the beam images to facilitate automated laser alignment.

One such beam image, known as the corner cube reflected pinhole image,



A sample set of corner cube reflected pinhole images.

exhibits wide beam quality variations that are processed by a matched-filter-based algorithm. The challenge is to design a representative template that captures these variations while at the same time assuring accurate position determination. The new,

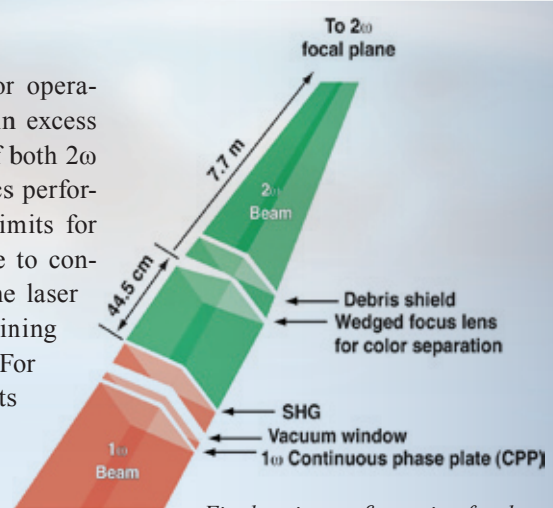
higher-accuracy templates are constructed to exploit several key recurring features observed in the beam images. A paper describing the template was presented at the August SPIE Optics+Photonics Conference in San Diego.

NIF Achieves Record High Energy Green Light

An essential feature of NIF is the final optical system that converts the fundamental 1,053-nanometer (1- ω , or 1ω) infrared light to higher harmonic frequencies and focuses it onto the target. This optical system is designed to be flexible to support a variety of missions. In a recent issue of *Applied Optics* (*Appl. Opt.* 47, 3494-3499 (2008)), NIF researchers report on the performance of a single NIF beamline at its second-harmonic wavelength of 526.5 nm (2ω). Record single-beamline pulsed energies were produced up to 17.7 kilojoules (kJ) (equivalent to 3.4 megajoules (MJ) for the full 192-beam NIF). Shaped pulses with focal spot smoothing were produced at energies that are consistent with high-energy-density experimental designs, including high-gain, high-yield 2ω ignition.

The possibility of using NIF at 2ω , or green light, has been a topic of study

for some time. The potential for operation at very high 2ω energies, in excess of 3MJ, has motivated studies of both 2ω target performance and 2ω optics performance. The increased fluence limits for optical damage make it possible to consider routine 2ω operation of the laser at these energies while maintaining or reducing operating costs. For example, during the experiments described in the *Applied Optics* report, with shots up to 3.4 MJ full NIF equivalent, no optical damage due to 2ω operations was observed. Target effects related to laser-plasma interactions are less well characterized at 2ω than at 3ω , but are expected to be mitigated by using larger, lower-temperature hohlraums. Because of the higher energies available at 2ω , these larger targets have calculated yields as high as 100 to 200 MJ.



Final optics configuration for the 2ω (green light) campaign. The second-harmonic generator (SHG) lens is a 2ω design with the correct wedge angle and focal length to focus green light on the target. A continuous phase plate for shaping the focal spot resides in the 1ω section and can be inserted into or removed from the beam depending on shot requirements.

OMEGA Laser Will Test NIF Direct-Drive Beam Smoothing

A production NIF preamplifier module (PAM) is being installed in the OMEGA Extended Performance Laser System (OMEGA EP) at the University of Rochester's Laboratory for Laser Energetics to study NIF beam smoothing with two-dimensional smoothing by spectral dispersion (2-D SSD).

Using 2-D SSD on NIF's beamlines is important for successful direct-drive ignition, which will be attempted on NIF after initial experiments using indirect drive have been completed. Indirect-drive ignition focuses NIF's lasers on the inside of a hohlraum containing the target capsule, generating an X-ray "bath" that causes the target to implode and ignite, while direct-drive focuses the laser beams directly on the ignition target.

Direct-drive ignition will require significant engineering modifications to the PAM design and will also require that NIF be operated at a high bandwidth.



A NIF preamplifier module being installed in the OMEGA EP Sources Bay will be used for beam-smoothing studies.

OMEGA EP experiments aimed at validating NIF laser-system performance and single-beam uniformity with 2-D SSD will be accomplished by making 2-D SSD modifications on the production NIF PAM and using

it as an alternate OMEGA EP front end. Installation of the PAM in the OMEGA EP Laser Sources Bay is scheduled to be complete by January 2009, and the initial deployment of 2-D SSD on the PAM is scheduled for the end of Fiscal Year 2009.



The software-based AAPLF automatic control system is monitored by a beam control operator at a console in the NIF control room.



Automated Alignment System Wins R&D 100 Award

NIF & Photon Science's autonomous alignment process for laser fusion systems (AAPLF) has earned an R&D 100 Award as one of the top 100 industrial innovations of 2007. AAPLF is a distributed software application in which coordinated processing of sensor video images and motorized optical adjustments using several hundred computers achieves the laser alignment tasks. AAPLF performs 26 separate optical adjustments on each of NIF's 192 beams in less than 15 minutes. To date, AAPLF has successfully fired and aligned NIF beamlines for more than 1,200 full system and 30,000 preamplifier shots.

Long-Duration Backlighting Experiments Are Successful

NIF's Amy Reighard and LLNL colleagues have successfully demonstrated a 7.5-nanosecond-duration pinhole-apertured backlighter at the OMEGA laser facility at the University of Rochester. Pinhole-apertured point-projection backlighting for 8 ns will be useful for imaging evolving features in experiments at NIF. The backlighter consisted of a 20-micron-diameter pinhole in a 75-micron-thick tantalum substrate separated from a zinc emitter (9 keV) by a 400-micron-thick high-density carbon piece. The carbon prevented the shock from the laser-driven surface from reaching the substrate before 8 ns and helped minimize X-ray ablation of the pinhole substrate.

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Operated by Lawrence Livermore National Security, LLC for the Department of Energy's National Nuclear Security Administration

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